Chapter 3 – The Science Content Standards
Grade Seven: Focus on Life Science

INTRODUCTION

We are fortunate to live in an exciting time for the study of life sciences. Our knowledge of biological systems is expanding rapidly and the development of new technologies has led to major advances in medicine, agriculture, and environmental management. A foundation in modern biological sciences with an emphasis in molecular biology is essential for future public school science teachers, college and university science professors and researchers, and those who will work in technological fields.

Another definitive reason for a focus on life science in seventh grade is the students' own biological and behavioral transition into early adolescence. Young adolescents make decisions that can have an enormous influence on their lives. The study of life science provides a knowledge base upon which they can make well-informed and wise decisions about their health and behavior. The relevance of the curriculum to students' lives will help maintain their interest in science and encourage young adolescents to continue to build their knowledge of the natural sciences.

The Health Framework for California Public Schools, Kindergarten Through Grade 12 is a valuable resource for science teachers. It contains grade level expectations for health education that provide important connections to the life science curriculum. In addition there are specific statutes that require parental notification regarding the teaching of topics related to human growth and development.

STANDARD SET 1: Cell Biology

Background

In the middle grades, students expand their knowledge of living systems to include the study of cells, the fundamental units of life.

In the fifth grade life science standards, students learned about the organs or tissues for respiration, digestion, waste disposal and transport of materials in plants and animals. They were first introduced to cellular functions in fifth grade when they studied cellular respiration in animals and plants, and photosynthesis in plants. These studies are complemented in the seventh grade by new material on the cellular organelles responsible for these functions.

The sixth grade standards covered ecology, and students in that grade learned how energy in the form of sunlight is transformed by producers into chemical energy through the process of photosynthesis. The study of energy transfer through food webs provided a foundation for a more detailed exploration at the cellular level of how plant chloroplasts capture sunlight energy for photosynthesis, and how mitochondria liberate energy for the work that cells do.

Description of the Standards

1. <u>All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope.</u> As a basis for understanding this concept:

a. Students know cells function similarly in all living organisms.

There are fundamental aspects of cell function that are similar regardless of the organism in which the cell resides. For example, cells contain a DNA genome and express the genome using a universal genetic code. The biochemical pathways in cells, such as those for cell division and energy production, are strikingly similar even though the cells serve different functions in and between organisms. Many proteins synthesized by cells have similar functions such as serving as enzymes that promote chemical reactions in the cell. There are significant functional differences between cells in an organism as they become “differentiated” or specialized, for example, a liver or a brain cell. There are also significant differences between cells in different environments such as the Escherichia bacterium living in an intestine or a Thermophilus bacterium living in a superheated geyser. Biological science has been greatly advanced by uncovering both similarities and differences among cells.

b. Students know the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.

Plant cells are surrounded by a cell wall (made primarily of cellulose) that is rigid and constrains the shape of the cell membrane. Animal cells are not surrounded by a cell wall and their shape is defined by their underlying cytoskeleton. Many plant cells contain chloroplasts and a central vacuole, neither of which are found in animal cells. These differences between plant and animal cells may be apparent by microscopy, using sections of plant and animal tissue that have been appropriately stained to highlight the structures. Images of cells are also available on the Internet and in textbooks. Labeled diagrams will help students learn about structures that are too small to be resolved with classroom microscopes.

c. Students know the nucleus is the repository for genetic information in plant and animal cells.

Chromosomes containing genes reside in the nucleus. When observing an interphase cell using a light microscope, the nucleus may appear to be homogeneous inside. This is because the chromosomal DNA is not condensed. In an appropriately fixed and stained section of onion root (which may be obtained from commercial sources), this DNA will be visible as a disk-shaped area, apparently constrained within a nucleus. This is the best stage to visualize DNA in support of learning the content of the standard. If the root tissue had a high rate of growth at the time it was sectioned and fixed, a fraction of the cells may be in one of the stages of mitosis. In that case the chromosomes will be visibly condensed but not constrained by a nuclear membrane. This must be explained carefully so that students do not develop a misconception about the distribution of DNA in a cell that is based solely on their observation of mitotic chromosomes.

d. Students know that mitochondria liberate energy for the work that cells do and that chloroplasts capture sunlight energy for photosynthesis.

Students may already understand that the food they eat provides them with energy in an informal sense. At the cellular level, the mitochondrion is responsible for efficiently extracting the chemical energy from molecules that has mostly been broken down from ingested food. The energy liberated by mitochondria is still stored in the form of chemical energy but in molecules that are readily accessible for energy release. Chloroplasts use pigments to absorb the energy in sunlight. This captured energy is used to drive a chemical reaction within the chloroplast in which carbon dioxide from the air is used as a source for carbon to form sugar molecules from which mitochondrion extract energy used in the cell.

e. Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.

Just as living organisms are said to have a "life cycle" that relates to their periods of growth and reproduction, cells are said to have a "cell cycle." Cells reproduce themselves by a process called mitosis. This takes place after a period of growth during which the DNA in the nucleus is replicated and cytoplasmic organelles, such as mitochondria and chloroplasts, are doubled in number. During mitosis, the replicated DNA chromosomes are segregated so that each daughter cell receives exactly the same number of chromosomes of each type (e.g. two of each type in a diploid organism). Students may visualize mitotic chromosomes by light microscopy in a stained section of rapidly growing tissue. Time-lapse videos and movies of cell division will also help to illuminate the process of chromosome segregation.

f. Students know that as multicellular organisms develop, their cells differentiate.

In most multicellular organisms, there is a division of labor among cells. Some cells in humans are brain cells, others are stomach, skin or muscle cells, but while these cells are clearly different their ancestry can be traced back to a single fertilized egg. During development of an embryo, some cells become fixed in their developmental program and are said to have "differentiated." For example, cells that will eventually divide to give rise to the stomach and intestines are distinguished at a very early stage from cells that will divide to give rise to the central nervous system and eyes. At later stages of development, a more fine-grained differentiation takes place. For example, some cells in the retina of the eye become rod cells (for vision in dim light) and others become cone cells (for color vision). Upon differentiation, most cells in humans lose the ability to become other types of cells.

In plants, cells often retain the ability to differentiate into other tissues. A leaf of an African violet for example, can set roots in soil and develop into a new plant. While the leaf is clearly differentiated, it is not fixed in its developmental potential in the way that animal cells typically are (an exception being the animal's germ cells that lead to eggs and sperm).

STANDARD SET 2: Genetics

Background

Genetics is the study of the biological processes involved in the transmission of the unique characteristics of an organism to its offspring. Discovering the genetic principles and mechanisms that explain growth, senescence, and heredity has been a great accomplishment of modern science. Gregor Mendel's studies of pea plants revealed the concept of genes and the rules for the inheritance of traits. Today we understand that these rules are a consequence of the chemical composition and structure of DNA. Seventh grade students will learn some of these rules that will serve as a foundation for high school biological sciences. .

Description of the Standards

2. A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:

a. Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms.

Sexual reproduction entails fertilization which in animals is an event requiring the fusion of an egg cell with a sperm cell. The fertilized egg (the zygote) goes through a series of cell divisions (mitosis) and developmental steps to generate a new organism genetically related to its parents. Pollination of flowering plants and growth of a new genetically-related plant from seed should also be presented as examples of a sexual life cycle.

Some organisms exclusively reproduce without a fertilization event. This is called “asexual” reproduction. Protists (single-celled eukaryotic organisms) often have no known sexual cycle and reproduce solely by mitotic division. Fungi and plants often have both sexual and asexual methods of reproduction. For example, plants can be propagated from a seed (sexual) or a cutting (asexual). While a seed is related to two parental plants, a cutting is genetically identical to the plant from which it was taken. Some primitive animals such as the flatworm Planaria can divide themselves into two genetically identical organisms asexually. Asexual reproduction should not be confused with reproduction in primitive animals such as nematodes. This should not be confused with hermaphroditic sexual reproduction that entails fusion of eggs and sperm generated by a single organism.

b. Students know sexual reproduction produces offspring that inherit half their genes from each parent.

Sexual reproduction combines the genetic material from two different cells. In most animal species, including humans, the genetic information is contributed from two different parents, nearly half from the biological mother and half from the biological father. It should be noted that mitochondria DNA is derived solely from the mother, making possible to trace heritage from grandmothers to grandchildren with great certainty. During fertilization, the egg and sperm cells combine their single sets of chromosomes to form a zygote containing two sets, or the diploid number, of chromosomes for a species (half from each parents).

c. Students know an inherited trait can be determined by one or more genes.

In the previous standard, the idea of "genes" was introduced to students as something inherited from each parent in roughly equal quantity. This standard draws a correlation between genes and the inherited traits or features of an organism. Attached or unattached earlobes is an inherited trait typically determined by a single gene (inherited from each parent). It is very likely that attached or unattached earlobes is just one visible manifestation of that particular gene which may have many other important roles during development that have not been catalogued. A single gene can affect more than one trait or feature in an organism. Many traits, such as hair and eye color, are determined by multiple genes and do not have simple patterns of inheritance. While an organism's genes define every inherited trait, there is not always a one-to-one correspondence between trait and gene.

d. Students know plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.

This standard introduces some of the principles of Mendelian genetics. The most significant concept is that genes exist in multiple versions, called alleles, and that these units of heredity are not typically changed during mating. Prior to acceptance of Mendel's laws, people believed that the mixing of genetic information was similar to mixing paint; the information (like red or white paint) could be blended to form a combined version (like pink paint) that could be blended still further (making it more white or more red). Using true-breeding strains of peas with variation of a single gene (such as flower color), Mendel showed that this model of blending was incorrect.

In seventh grade, they will learn that every person has tens of thousands of genes and that there are slight variations or "alleles" of these genes in every individual. Using the correct vocabulary is important: A person with a genetic disorder does not "have the gene for that trait," but rather it might be said that the person "has the genetic allele for that trait." Every person has every gene (and usually in two copies), but some people have an abnormal or different version (or versions) that can lead to a disorder or different trait. The genetic traits of an individual are determined by which alleles of genes are inherited from each parent and how those alleles work together. Some alleles are dominant, meaning that they overcome the influence of the other (recessive) alleles. In seventh grade students learn to interpret the genotype-phenotype relationship in offspring, for example on a pre-made Punnett Square diagram. In high school biology, students will learn many of the details of genetics. This is a foundation for transmission genetics in high school biology and therefore the details of genetics, including the construction of the Punnett Square model, can be deferred.

e. Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.

Chromosomes in eukaryotes are complexes of DNA and protein. They organize the genetic make-up of a cell into discrete units. Humans, for example, have 23 pairs of chromosomes that vary in size. When looking through a microscope at an appropriately stained section of onion root tip, students may see cells that are engaged in mitosis and have visible, condensed chromosome structures. The proteins in a chromosome help to support its structure and function but the genetic information of a cell is uniquely stored in the DNA component of the chromosome.

STANDARD SET 3: Evolution

Background

In second grade, students developed simple notions of inheritance and variation within a species. These are foundational for the study of evolution, as are the third grade studies of adaptations to an environment and processes of extinction. Charles Darwin was a naturalist who traveled widely, and third grade students are "retracing his steps" when they develop their knowledge of organisms in a wide variety of earth biomes. Fourth grade students learn about the survivability (or fitness) of plants and animals in an environment and sixth grade students are provided with a background in earth science. These standards all provide a foundation for learning about natural selection in the seventh grade and understanding the fossil record to be a line of evidence for the evolution of plants and animals.

Description of the Standards

3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept:

a. Students know both genetic variation and environmental factors are causes of evolution and diversity of organisms.

In second grade, students learned that some characteristics of an organism are inherited from the parents and some are caused or influenced by the environment. They also learned that there is variation among individuals in a population. This standard takes these simple ideas to much greater depth, by explicitly referring to "genetic variation" and "environmental factors." Environmental factors are a cause of natural selection, but as the term "selection" implies, there must also be favorable and unfavorable traits uncovered in the population. The genetic variability must precede natural selection, or there is some risk that no individuals in the population will survive a crisis. This principle is evident in the worldwide cheetah population, and in other endangered species with a high degree of genetic homogeneity. With little genetic variation to spread the risk, a population is more susceptible to extinction, for example by succumbing to an infectious disease for which there is no natural resistance.

b. Students know the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.

Charles Darwin explained his line of reasoning for natural selection as the primary mechanism for evolution in his book On the Origin of Species by Natural Selection. Darwin proposed that differences between offspring would occur randomly. Some of these differences will be inheritable and affect an individual offspring’s ability to survive and reproduce within a particular environment and ecological setting. With the passage of succeeding generations, those individuals best suited to particular environments will tend to leave more progeny and those less well suited would have fewer progeny or even become extinct. Darwin called this process “natural selection” because environmental and ecological conditions essentially “select” certain characteristics of plants and animals for survival and reproduction. Darwin proposed that over very long periods of time, natural selection acting on different individuals within a population of organisms could account for all of the great variety of species we see today, and for the great number of extinct and non-extinct species found in the fossil record. Darwin's proposal that natural selection is the mechanism for evolution was drawn in part from the ideas of Thomas Malthus in his book, On the Principle of Population. Malthus presented his argument that human populations have a tendency to grow faster than their food supply which causes shortages and a "struggle for existence." Darwin's observations in the Galapagos Islands led him to think that this "struggle for existence" might be generalized to animals and plants.

c. Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the basis for the theory of evolution.

Independent lines of evidence from geology, the fossil record, molecular biology, and studies of comparative anatomy support the theory of evolution. Many decades before Darwin proposed his theory, geologists knew that sedimentary rocks formed an important history of life on Earth, with geologically younger rock layers usually near the top, and older layers successively closer to the bottom of sedimentary formations. Sometimes the normal sequence of sedimentary layers has been overturned by tectonically caused folding and faulting, resulting in older rock units resting on top of younger units. Some of the organisms that lived in or were buried by the original sediment were preserved as fossils while the sediment hardened into rock. Original material (e.g., shell and/or bone) may be preserved, but chemical alteration and preservation may also be involved. The process of fossilization preserves evidence of ancient life forms, and geologic interpretation of the enclosing sedimentary rock yields valuable information about the environments in which these ancient organisms lived. Paleontologists find more recently evolved organisms in the geologically younger layers of sedimentary rocks while more ancient life forms are found in the older layers of rocks. Radioactive dating provides another highly accurate method to confirm the age of rocks and fossils. Comparative anatomists study similarities and differences among organisms. They have been able to discover significant similarities in the skeletal architecture and musculature of all vertebrates from fish to humans. The most plausible explanation for this finding is that all vertebrates descended from a common ancestor.

d. Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.

Evolutionary relationships among living organisms and their ancestors can be displayed in a diagram that resembles a branching tree. Groups of similar living species belong to a genus, similar genera belong to a family, similar families belong to an order, similar orders belong to a class, and similar classes belong to a phylum. Working back in time from the shared derived characteristics of each individual living species contained in the diagram will show the evolutionary relationships leading back to a common ancestor. The classification of organisms according to their characteristics is called "systematics." It is based on a system developed in 1758 by the Swedish botanist and explorer Carolus Linnaeus.

e. Students know that extinction of a species occurs when the environment changes and that the adaptive characteristics of a species are insufficient for its survival.

Extinction of a species occurs when its adaptive characteristics are no longer sufficient to allow its survival under changing environmental conditions. Evidence from the fossil record indicates most of the species that once lived on Earth are now extinct. Biological adaptations are produced through the evolutionary process. Random mutations in the DNA of different individuals (plants or animals) produce variations of particular traits in a population of organisms. These mutations result in some individuals acquiring characteristics that give them and their offspring an advantage for surviving and reproducing in their present environments or in a different environment. The offspring of those individuals in which these advantageous characteristics are not present may decline in numbers and become extinct over time or may continue to coexist with the offspring of individuals with the advantage. Natural selection will then lead to the existence of populations better able to survive and reproduce under any one particular environmental condition. However, when particular adaptive characteristics of a species are no longer sufficient for its survival under changing environmental conditions (such as increased competition for resources, newly introduced predators and/or loss of habitat) that species can become extinct. There are many different environmental causes for species extinction.

STANDARD SET 4: Earth and Life History

Background

The process of natural selection is strongly linked to the environment which, as students will learn in this standard set, has changed over time. The geological record provides evidence of both the environments and the plants and animals that inhabited them in the past. The focus in these standards is on utilizing the geological evidence to better understand life on earth, past and present.

To understand how life and geology are related there are two great ideas from the geological sciences presented in this standard set: 1) the concept of uniformitarianism and 2) the principle of superposition. Uniformitarianism refers to using features, phenomena, and processes that are observable today to interpret the ancient geologic record. The idea is that small, slow changes can yield large cumulative results over long periods of time. Standard 4c states a simplified version of the principle of superposition when it indicates that the oldest rock layers are generally found at the bottom of a sequence of rock layers. The principle of superposition is the basis for establishing relative time sequences (i.e., determining what is older and what is younger). Geological records indicate that both local and global catastrophic events have occurred including asteroid/comet impacts that have significantly affected life on Earth. Both the evidence and the impact on life should be addressed in this standard set.

Description of the Standards

4. <u>Evidence from rocks allows us to understand the evolution of life on Earth.</u> As a basis for understanding this concept:

a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

This standard approaches two different but related ideas in the geologic sciences. The first (uniformitarianism) uses the present as the key to the past. For example, ripples preserved in ancient sedimentary rock are identical to ripples made by running water in mud and sand today. This is but one example of how geologists use the present to interpret features and processes in the geologic past. The second idea states that the vastness of geologic time allows even very slow processes, if they continue long enough, to produce enormous effects. Perhaps the most important example of this is the dramatic change in the arrangement of the Earth's continents (continental drift) caused by slow movement of lithospheric plates (~5 centimeters/year) during the course of many millions of years. It should be noted that one piece of evidence for plate tectonics, including Pangaea, is the fossil record. The coherence of species in the fossil record is seen when the geological history is properly understood.

b. Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impact of asteroids.

The subject of major catastrophic events is important because, although rare in the history of the Earth, such events have had a significant effect both on shaping the surface of the Earth and on the paths of evolutionary development of life. Most of the time, geologic processes go forward almost imperceptibly only to be periodically interrupted by the impact of a large meteor or by a major volcanic eruption. The immediate effect of both of these catastrophic events is much the same; injection of large amounts of fine-grained particulate matter into the atmosphere which can have immediate regional or even global consequences for the climate, causing both short- and long-term changes on habitats.

c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.

Whenever rocks are uplifted and exposed to the atmosphere they are subjected to processes which can break them down. Purely physical processes, such as abrasion and freezing/thawing cycles, break rocks into smaller pieces. At the same time, reactions with constituents of the atmosphere, principally acidic rain and oxygen, may cause chemical changes in the minerals which make up the rocks, causing new types of minerals to form. The net result is called sediment. It consists of rock and mineral fragments, various dissolved ions, and whatever biological debris happens to be lying around. This sediment is removed by erosion from the sites where it formed and is transported by water, wind, or ice to other sites where it is deposited and eventually lithified to form new sedimentary rock. As the sediment accumulates, the biological portion may be fossilized and preserved, providing a partial record of existing life in the sediment's source area.

Superposition, the fossil record, and related principles, such as crosscutting and inclusions, together form the basis for dating the relative ages of rocks. Students should realize that relative dating only gives the order of events, not quantitative estimates of when those events actually occurred.

d. Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.

Relative age-dating (see 4c above) provides information about the relative sequence of events in the history of the Earth. Absolute dating (putting a numerical estimate on the age of a particular rock sample) requires the use of a reliable "clock" in the form of the radioactive decay of certain naturally-occurring elements. These elements are segregated into specific minerals at the time those minerals are formed, generally during the crystallization of igneous rocks. Thus, the newly formed minerals in the igneous rock contain only the original radioactive form of the element ("parent") and none of the products of radioactive decay ("daughter products") which are elements different from the parent. The rate of transformation from parent to daughter elements by radioactive decay can be measured experimentally. This rate is usually expressed as a half-life which is defined as the amount of time it takes to change one-half of the atoms of the parent element to daughter products.

The earth's surface is always being reworked because of plate tectonics and erosion so very little "original" earth material is available for dating. However, moon rocks and meteorites, thought to be the same age as the earth, can also be dated. All the available evidence, from the oldest known earth rocks and extraterrestrial material, points to an earth and solar system approximately 4.6 billion years old. The earliest rocks containing evidence of life are about 3.0 billion years old.

e. Students know fossils provide evidence of how life and environmental conditions have changed.

Fossils provide evidence of the environments and types of life that existed in the past. As an ancient environment changed, so did the organisms it supported. Thus environmental changes are reflected by the classes of organisms that evolved during the period of environmental change. Uniformitarianism is the foundation on which these interpretations are based. For example, ancient animals exhibiting approximately the same shell shape and thickness as the modern clam probably lived in the same environment as clams do today. By noting changes in life types with time, based on fossil evidence, geologists can reconstruct the environmental changes that accompanied (perhaps caused) the changes in life types.

f. Students know how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographical connections, have affected the past and present distribution of organisms.

Darwin's work on Galapagos Island finches demonstrated clearly the effect of isolation on the distribution of organisms. Geographical separation of individuals in a species prevents them from interbreeding. This can lead to the accumulation of genetic changes in the two populations that eventually define them as different species. Plate tectonic movements of lithospheric plates and the uplift of mountain ranges divide (albeit slowly) populations of plant and animal species and isolate the divisions from each other. This has been illustrated in the fossil record of dinosaur species, some of which were uniformly distributed prior to continental separation, as well as other species that were restricted to specific continents after geologic separation.

g. Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.

Many of the changes that life has undergone over the history of the earth have been gradual, occurring as organisms either adapt to slowly changing environments, evolve into new species, or become extinct. This is a fundamental tenet of uniformitarianism. But even uniformitarianism is not consistently true. For example, the very early Earth on which the first life appeared was considerably different from the planet of today. For example, there was little oxygen in the atmosphere, and no ozone layer in the stratosphere to protect against harmful solar radiation. The earliest life was therefore anaerobic and had to be protected from solar radiation. Evidence for this single-celled life can be found in rocks as old as 3.5 billion years.

An early addition to the prehistoric ecosystem were the photosynthetic cyanobacteria, once referred to as blue-green algae. These early organisms are seen in the fossil record and were very successful, indeed so much so that they still exist worldwide and are essentially unchanged in form after billions of years.

Slow change in Earth's life has been punctuated by sudden events – “catastrophic” when viewed on the vast geological time scale. One such remarkable event occurred about 600 million years ago. It is known as the Cambrian Explosion because of the sudden appearance of many different kinds of life, including many new multicellular animals which, for the first time, had preservable hard parts such as shells and exoskeletons.

At various times life on Earth has also suffered from catastrophic mass extinctions in which the vast majority of species quickly died out. The greatest such event happened around 250 million years ago toward the end of the Paleozoic Era. It is known as the Permian extinction, and as many of 90% of marine species may have died out. Another famous mass extinction occurred at the end of the Mesozoic and is known as the Cretaceous/Tertiary (KT) extinction. At this time all species of dinosaurs died out, as did about half of all the plant and animal groups. Evidence is mounting that this catastrophic event was caused by the impact of an asteroid.

STANDARD SET 5: Structure and Function in Living Systems

Background

Students were first introduced to the complementary nature of structure and function in the first grade when they studied the different shapes of animal teeth and inferred what kinds of food those animals eat. Third grade students studied external physical characteristics of organisms and considered their functions as a matter of adaptation. Seventh grade students will deepen their understanding of internal structures, a topic that was started in the fifth grade.

The internal structures of living organisms are considered at different levels by anatomists and physiologists. Mammals have discrete organs, many of which work together as "systems". For example, the adrenal and pituitary glands are parts of the endocrine system, and the kidney and bladder are parts of the excretory system. Flowering plants have tissues such as xylem and phloem that are part of a vascular system. Organs themselves may have specific tissues, for example the white and gray matter of the brain, which can serve multiple functions. For example, the pancreas is both the site of production of digestive enzymes and blood hormones.

Seventh grade students learn about the skeletal and muscular systems, the basic functions of the reproductive organs of humans, and the structures that help to sustain a developing fetus. Students also study the intricate structures of the eye and ear, which have well-understood functions in sight and hearing. While a wide variety of topics are covered in this section, they are all grouped in the fields of anatomy and physiology.

Description of the Standards

5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:

a. Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.

Protists, such as amoebae, are made up of only one cell. All of the functions necessary to sustain the life of these organisms must be carried out within that one cell. Multicellular organisms, such as plants and animals, tend to have cellular specialization (differentiation), which means individual cells or tissues may take on specific functions within the organism. For example, the skeletal muscle system of animals is comprised of individual muscle groups (e.g. biceps) that are bundles of muscle fibers, which are themselves groups of muscle cells, working together to make movements of the organism possible. Within individual muscle cells are organelles, such as the mitochondria, that help provide the energy for muscle contraction.

b. Students know organ systems function because of the contributions of individual organs, tissues and cells. The failure of any part can affect the entire system.

Students learned in fifth grade how blood circulates through the body and O_2 and CO_2 are exchanged in the lungs and tissues. This pulmonary-circulatory system functions as a whole because of the functions of its individual components. A person may die after a heart attack (failure of the heart), or as a result of suffocation or pneumonia (insufficient gas exchange in lungs), shock (from loss of blood volume) or stroke (sometimes caused by an insufficient gas exchange with brain tissues due to blockage of blood vessels).

c. Students know how bones and muscles work together to provide a structural framework for movement.

The skeletal system in animals provides support and protection. Skeletal muscles are attached to bones by tendons. Muscles work in coordination with the bones and the nervous system to cause movement of an organism through coordinated contractions and relaxations of different muscle groups. For example, the biceps muscle in the arm causes bending of the arm at the elbow so that the angle between the bones (humerus and ulna) decreases, while the triceps muscle on the back of the arm causes bending so that the same angle increases. This flexion and extension of the arm is a good example of muscle groups that are coordinated. Even in a lifting motion where one of these two muscle groups is ostensibly the prime mover of the bone (e.g., “curling” a weight with the biceps), the opposing muscle group is involved in producing a smooth, controlled motion of the arm and protecting the joint from strong contraction.

d. Students know how the reproductive organs of the human female and male generate eggs and sperm and how sexual activity may lead to fertilization and pregnancy.

In males, the testes, located within the external scrotum, are the reproductive structures that produce sperm. Immature sperm cells in the walls of the seminiferous tubules of each testis mature into flagellated cells that are transported and stored in the epididymis. During sexual arousal, millions of sperm may be transported to the urethra and ejaculated through the penis. Some sperm may exit through the penis before ejaculation (i.e. without the man's knowledge), and sexual activity that does not result in ejaculation may nonetheless lead to the release of sperm, fertilization, and pregnancy.

In females, the ovaries are the reproductive structures that produce and store eggs, also called "oocytes" (pronounced "oh-oh-sights"). An egg develops within an ovarian structure called a follicle. A mature follicle can rupture through the wall of the ovary releasing the egg during the process of ovulation. The egg is then transported by one of the Fallopian tubes to the uterus. If, at or around this time, the female engages in sexual activity that results in sperm being deposited in or near the vagina, a sperm cell can travel through the vagina to the uterus or Fallopian tubes and fertilize the egg. A fertilized egg may implant in the uterus and develop, meaning that the woman is pregnant and may deliver a baby approximately nine months later. If the fertilized egg fails to implant and begin development, or if the egg is not fertilized, it will be sloughed off along with several layers of cells lining the uterus and passed out of the female's vagina during menstruation. One of the first signs of pregnancy is that a woman's regular monthly menstrual cycles stop.

e. Students know the function of the umbilicus and placenta during pregnancy.

The placenta is an organ that develops from fetal tissue in the uterus during pregnancy. It is responsible for providing oxygen to the developing fetus. The umbilical cord (which enters the body at the "umbilicus" or navel) is a cord containing arteries and veins that connect the fetus to the placenta. While the blood of the mother and her fetus do not mix together, oxygen and nutrients pass from the mother's blood to the fetus, and wastes such as carbon dioxide from the fetus are removed. While the placenta helps to nourish and protect the fetus, most drugs and alcohol can easily pass from the mother's blood into the blood of the fetus, as can many infectious viruses such as HIV (the AIDS virus).

f. Students know the structures and processes by which flowering plants generate pollen, ovules, seeds, and fruit.

Flowering plants, the angiosperms, reproduce sexually by generating gametes in the form of sperms and ova. The reproductive structure of the angiosperms is the flower. It can contain either male or female parts, or both. Stamens are the male reproductive structures within the flower. Each stamen is composed of an anther, the structure that produces pollen granules and a filament, the long thin stalk that connects the anther to the base of the flower (receptacle). The pistil is the female reproductive structure located in the center of the flower. It is comprised of the stigma that receives the pollen grains, and the style, a long thin stalk that acts as a guide for the pollen tube. The pollen tube, in turn, provides a migration path for the sperm of the pollen grain down to the ovary at the base of the pistil. The ovary contains one or more ovules, inside of which develop the ova. After fertilization the ovule develops into a seed with the developing embryo inside surrounded by a food source (the endosperm) for the plant embryo. The surrounding ovary may then enlarge and mature into a fruit that can contain one or more seeds.

g. Students know how to relate the structures of the eye and ear to their functions.

The eye is very much like a camera. It is equipped with a lens that brings an image into focus on a sheet of light-sensitive cells called the "retina" which is equivalent in a camera to a sheet of film or a CCD video chip. The amount of light entering the eye is controlled by the iris which is an adjustable circular aperture. In bright lighting, the iris contracts and the pupil (the open area that appears black) becomes smaller in diameter to admit less light. In dim lighting, the iris relaxes and the pupil becomes larger to admit more light. The lens of the eye refracts (or bends) the light, much as a magnifying glass does, and focuses an image on the retina. The lens is flexible and its shape changes when focusing on nearby or distant objects. The retina contains cells that are sensitive to bright colors (cone cells) and others that are sensitive to dim lighting (rod cells). The cells in the retina generate an electrical signal that travels to the brain which can interpret the visual pattern. The optics of sight are described in Standard Set 6 and the investigative activities with lenses can be applied to this section as well.

The external ear (i.e., the part that can be seen on the outside of the body) helps to collect sound waves and direct them to the middle ear. Many mammals (e.g., cats and many breeds of dogs) can redirect their external ears to detect faint sounds and determine the direction from which a sound is coming. The middle ear consists of a vibrating eardrum or "tympanic membrane" and three small bones (the malleus or "hammer", incus or "anvil", and stapes or "stirrup") that form a series of levers connecting the eardrum to the inner ear. Two small muscles control the tension on the eardrum and middle ear bones to reduce or increase the loudness of sound being transmitted. The inner ear, or labyrinth, contains the sensory cells that turn the waves of sound (or pressure) into electrical signals that are sent to the brain.

Students can explore the structure of the mammalian eye by performing a dissection. They should be able to identify and explain the function of the different parts of the eye. Students can learn the structure and function of the human ear by building a model from simple materials. They should be able to identify the different parts of the ear and explain how these parts work together to transmit sensory information in the form of sound waves that stimulate the sensory cells lining the cochlea, causing nerve impulses to be transmitted through the auditory nerve to the brain.

STANDARD SET 6: Physical Principles in Living Systems

Background

The study of optics and levers or pressure is usually reserved for physical science classes. However these topics are introduced for the first and only time in the seventh grade standards and it is important that students learn the principles behind them. Suggestions are made to relate to the idea that the eye, muscles, bones and tendons, and the heart can all be used in the study of these topics.

Sight is one of the five senses. Unlike touch, however, we do not "reach out and see" something (despite a comic book character's x-ray vision apparently emanating from within his eyes). Instead, our eyes contain receptors that detect incoming visible light that was either given off by a luminous object or reflected from an illuminated object. Until the early 1900's, physicists believed that the properties of light could be completely understood by viewing it as a wave of electromagnetic energy that could somehow be propagated through a vacuum – the so-called "ether". The nature of light still seems mysterious to most people because light manifests both wave and particle properties. In most of our experience, geometric optics, which treats light as rays traveling in straight lines, adequately explains reflection and refraction, mirrors, and lenses. Before starting this topic, students should be able to measure angles, do ratio and proportion problems, and use gram masses and meter sticks.

Understanding how levers can multiply forces or distances is important and accessible to students in the seventh grade. Given a lever, students can identify the fulcrum, effort distance, effort force, resistance distance, and resistance force. If any three of these quantities are known, students should be able to calculate the fourth quantity. Students can make simple levers and hinges (and other simple machines, if time permits) to show how levers can be used to increase forces at the expense of distances or distances at the expense of forces. Meter sticks, weight holders, hooked weights and pivoted supports are commercially available to make it straightforward to investigate the operation of levers. A key element of these standards is to relate the physical principles to the function of muscle and bone in the body. Pressure, a subject that has been introduced to students in the context of "atmospheric pressure" in earth science, is now discussed in the context of blood pressure and heart function.

Description of the Standards

6. <u>Physical principles underlie biological structures and functions</u>. As a basis for understanding this concept:

a. Students know visible light is a small band within a very broad electromagnetic spectrum.

Visible light is part of a continuum known as the electromagnetic spectrum that extends on both sides of the visible region. This includes wavelengths of the electromagnetic spectrum from the very long wavelengths, such as those of AM and FM radio and TV, to the somewhat shorter wavelengths such as radar, microwaves and infrared radiation, to visible light which has wavelengths just less than one millionth of a meter long. The wavelengths of electromagnetic radiation that the human eye can see vary from about 800 nanometers (0.0000008 m) or red light to 400 nanometers (0.0000004m meters) or blue/violet light. The colors of the visible spectrum are traditionally described as red, orange, yellow, green, blue, indigo, and violet, but actually form a continuous spectrum.

b. Students know that for an object to be seen, the eye must detect light emitted by or reflected from it.

This standard is about the physical principles of the interaction of light with matter.

Following this initial interaction, light rays from an object must pass from the object to our eye. The interactions with those parts of the eye that focus the light, creating an image on the retina, and transfer the light into electrical impulses, which are interpreted by our brain, all depend on the information in the light that enters the eye. This information arises from the initial interaction of the light with the object and/or the nature of the light emitted by the light source or sources. The color and brightness of light that is emitted or reflected from an object depends on the color, brightness and the angle of incidence from the source illuminating the object. The object then absorbs, reflects, or refracts the illuminating light and thereby imparts a color and brightness. We ascribe this color to the object but it really depends on the source of light and the way the object interacts with it. Note that this process scatters light in all directions. The eye only detects the light that enters the eye. This light first encounters the front, rounded, transparent surface of the eye (the cornea, where most of the focusing occurs). Next, it enters the interior of the eyeball through the pupil and passes through the lens that acts to further focus the light to accommodate both near and far objects. The focused light then falls on the receptors (the rods and the cones) in the retina, is converted into electrical impulses, and transferred by the optic nerve to the visual cortex of the brain.

c. Students know light travels in straight lines if the medium it travels through does not change.

In a vacuum or in a uniformly transparent material, light travels in straight lines. At the interface between two media or between vacuum and medium, light rays will bend if they enter at an angle other than perpendicular to the interface. The light bending properties of objects should be explored. Transparent materials, such as air, however, can have differing densities and cause light to bend as it passes through the material. For example, the air heated by a campfire can cause objects to appear to “shimmer” because the path of the light is not a straight line. The variations in the density of the atmosphere are what cause the stars to twinkle. When light travels from one transparent medium (such as air) into another transparent medium with different optical properties (such as water), the path taken by the light may bend (or be refracted) depending on the angle the rays of light make with the surface between the two media.

A pencil placed in a glass half full of water will look bent. By analyzing the path of the light from various points on the pencil to the eye of the observer, students will be able to confirm that the path of the light did change direction as it passed from one medium into another.

d. Students know how simple lenses are used in a magnifying glass, the eye, a camera, a telescope, and a microscope.

Combinations of lenses are used in telescopes and microscopes to magnify objects. The cornea of the eye plays the major role of a lens in transforming the rays of light diverging from an object into rays of light converging to a focus on the retina. Simple magnifiers of plastic (or glass) are cheap and easily obtained. A magnifier is a converging optic because it can convert rays of light diverging from an object to rays of light converging to form an image. Magnifiers are characterized by their focal lengths, which may be found by lifting a lens up from a table until the sharpest image of a ceiling light is formed. The distance from the magnifier to the image on the tabletop is the focal length. If the magnifier is held at a distance shorter than the focal distance above a printed page, the print is seen magnified, because the lens creates an enlarged, virtual image instead of a real image. If the magnifier is held at a distance greater than the focal length above the page, what is seen depends on where the observer's eye is located. The light leaving the lens is now converging so that, if the eye intercepts the converging rays, no sharp image will be seen. If the eye is located far enough above the page, the rays from the lens converge to form a real image and pass through it. The eye is now intercepting diverging rays and sees the print upside down.

e. Students know that white light is a mixture of many wavelengths (colors) and that retinal cells react differently to different wavelengths.

White (visible) light may be dispersed into a spectrum of colors from red at the longest wavelength to violet at the shortest wavelength. A glass or plastic prism disperses white light into the colors of the spectrum because the angle of refraction is different for the different wavelengths (colors). A diffraction grating of closely spaced grooves can also be used to separate white light into colors because different wavelengths (different colors) interfere constructively after reflection at different angles. Both of these effects should be presented to show the nature of white light. Seeing color, however, is due to specialized color light receptor cells in the retina of the eye. Specialized cells (called cones) in the retina of the human eye make color vision possible. The human perception of a wide range of colors can be controlled by printing just four colored dots (usually magenta, yellow and cyan along with a very dark purple or black) in patterns too small to perceive (resolve) with the human eye. This is an additive effect of creating color images commonly used in magazines.

f. Students know light can be reflected, refracted, transmitted, and absorbed by matter.

The interaction of light with matter is put into one of four categories; reflection, refraction, transmission and absorption. Light transmitted through air and transparent uniform materials continues to travel in a straight line. However, when rays of light encounter a surface between two materials or two media, such as air and water, or air and glass, the light can be reflected or refracted at the surface. The angle at which the light is reflected or refracted from its original line follows principles that depend on the optical properties of the materials. For example, the angle of incidence equals the angle of reflection. The principles of refraction are what make it possible for lenses to focus and magnify images.

Light travels through a transparent medium (is transmitted) by a process of absorption and re-emission of the light energy by the atoms of the medium. Opaque and translucent objects absorb and scatter light from their original direction much more strongly than transparent objects. Optically denser materials, like glass, cause light to travel more slowly than less optically dense materials, like water and, especially, air. Light travels through air just slightly more slowly than through a vacuum. Rays of light can be observed to change direction or refract (a consequence of light changing speed) in going from one medium to another. However, if light enters a new medium perpendicular to its surface, the light continues in a straight line so that refraction is not observed (even though the light is traveling at a different speed in the second medium). Impurities or imperfections in transparent materials or medium cause some of the light to be scattered out of the beam. Smoke, fog, and clouds scatter light which accounts for decreased visibility.

g. Students know the angle of reflection of a light beam is equal to the angle of incidence.

When a light beam encounters a shiny reflecting surface, the angle of reflection is the same as the angle of incidence. The angle is usually measured with respect to the surface normal.

h. Students know how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).

Archimedes is credited with first understanding that a rigid rod (a lever) able to rotate about a fixed pivot point (a fulcrum) can be used to turn a small force into a large force. Joints in the body act as pivot points for bones acting as levers, and muscles provide the force. There are three classes of levers depending on the relative positions of the applied force causing the action, the placement of the fulcrum, and the resistant object being moved. Levers provide one of two principal advantages. They can amplify the force being applied so that a small force applied over a long distance can create a large force over a short distance. This is useful in lifting heavy objects. Alternatively, typical of levers in the human body, a large force applied over a short distance in a short time can be amplified into long rapid motions, such as in running or in swinging a baseball bat.

i. Students know how levers confer mechanical advantage and how the application of this principle applies to the musculo-skeletal system.

A lever may be used to obtain a force advantage or a speed (or motion) advantage. A bone is the lever, a joint is the pivot point (or fulcrum), muscles supply the force, and connective tissues transfer the force to locations that usually give an individual the leverage to increase his or her speed of motion of foot, arm or hand. Students can make simple levers and hinges (and other simple machines, if time permits) to show how levers can be used to increase forces at the expense of distances, or distances at the expense of forces. Meter sticks, weight holders, hooked weights and pivoted supports are commercially available to make it straightforward to investigate the operation of levers. These or other hands-on lab activities with first, second and third class levers using simple equipment will make the "law of the lever" more real than solving a set of mathematical proportion problems or just identifying the parts of a lever from drawings or pictures.

j. Students know that contractions of the heart generate blood pressure and that heart valves prevent the backflow of blood in the circulatory system.

The heart is a pump in which blood enters a chamber through a blood vessel, a valve closes off the blood vessel to prevent the blood from flowing in the wrong direction, and the heart muscle contracts. This "squeezes" the blood and increases the pressure to force the blood out into another blood vessel. Pressure is defined as force per unit area and is measured in various units such as millimeters of mercury (mmHg). Students may learn more about the physiology of the heart by reading science texts, and studying models.

STANDARD SET 7: Investigation and Experimentation (I&E)

Background

The essential skills and knowledge for observing, communicating, and experimental design are extended in seventh grade. The inclusion of scale model building in the curriculum helps students to visualize complex structures. Collecting information from a variety of resources is an important part of scientific inquiry and experimental design. Many types of print and electronic resources are available in the school library to support teaching and learning science. Finding and identifying these sources is a complex skill that requires in some cases significant knowledge of the topic.

Description of the Standards

7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes and binoculars) to perform tests, collect data and display data.
b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.
c. Communicate the logical connection among hypothesis, science concepts, tests conducted, data collected, and the conclusions drawn from scientific evidence.
d. Construct scale models, maps and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).
e. Communicate the steps and results from an investigation in written reports and oral presentations.